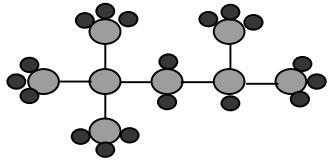
ALKYLATES
Key Components in Clean-Burning Gasoline



Presented to

The Clean Air Act Advisory Committee

Panel on Oxygenate Use in Gasoline

By

K. Dexter Miller, Jr
DeWitt & Company Incorporated

May 24, 1999

ALKYLATES
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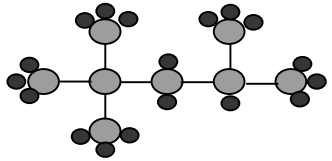
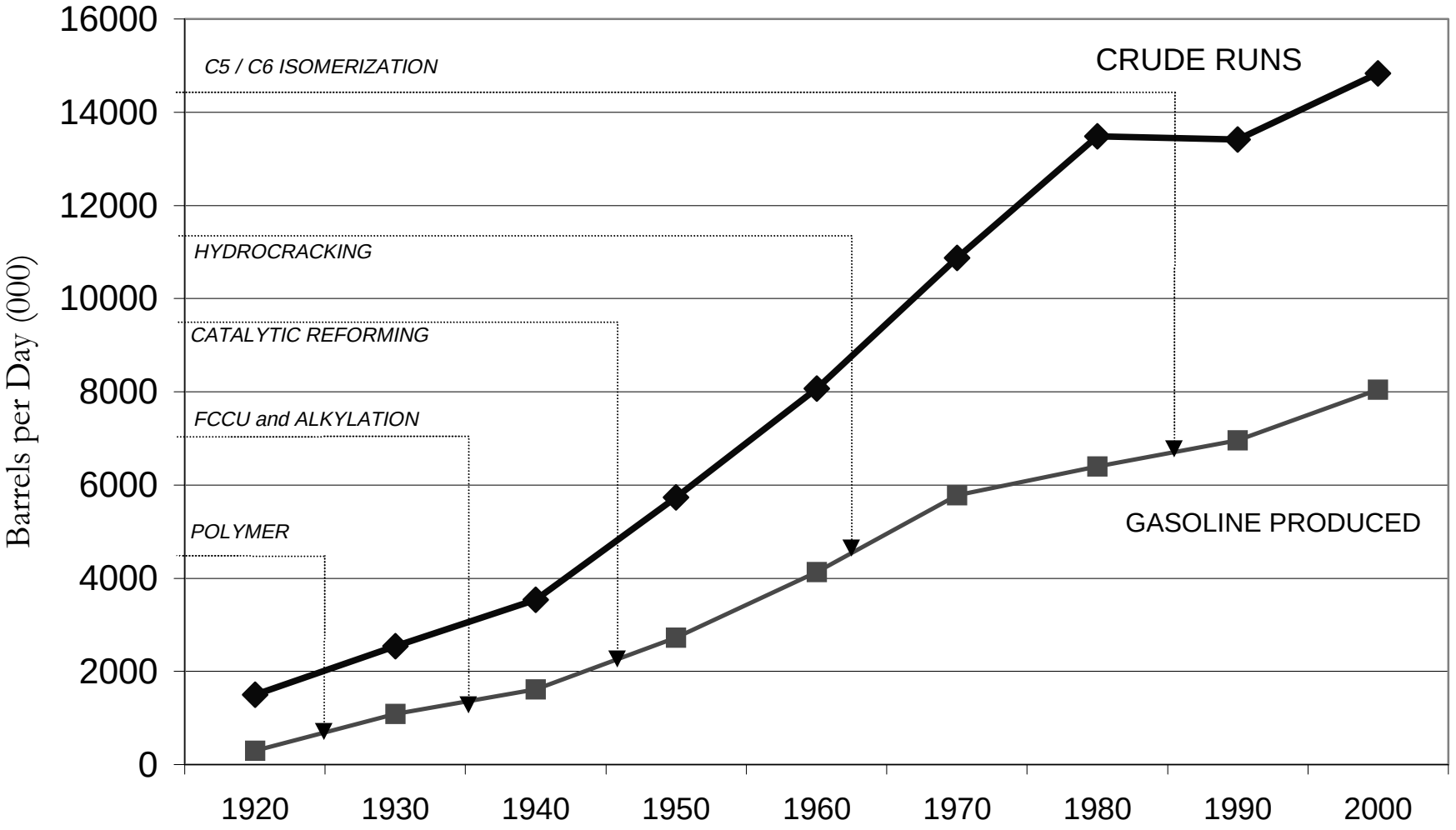


Historical Development of Gasoline Production:

Straight-run Gasoline to about	**1925**
Polymer Gasoline	**1930**
Cat Cracking & Alkylation	**1935**
Catalytic Reforming	**1940's**
Hydrocracking	**1960's**
Isomerization	**1980's**

Refinery Operations in the USA



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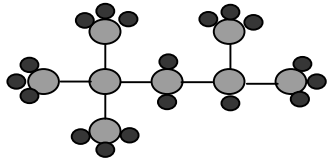
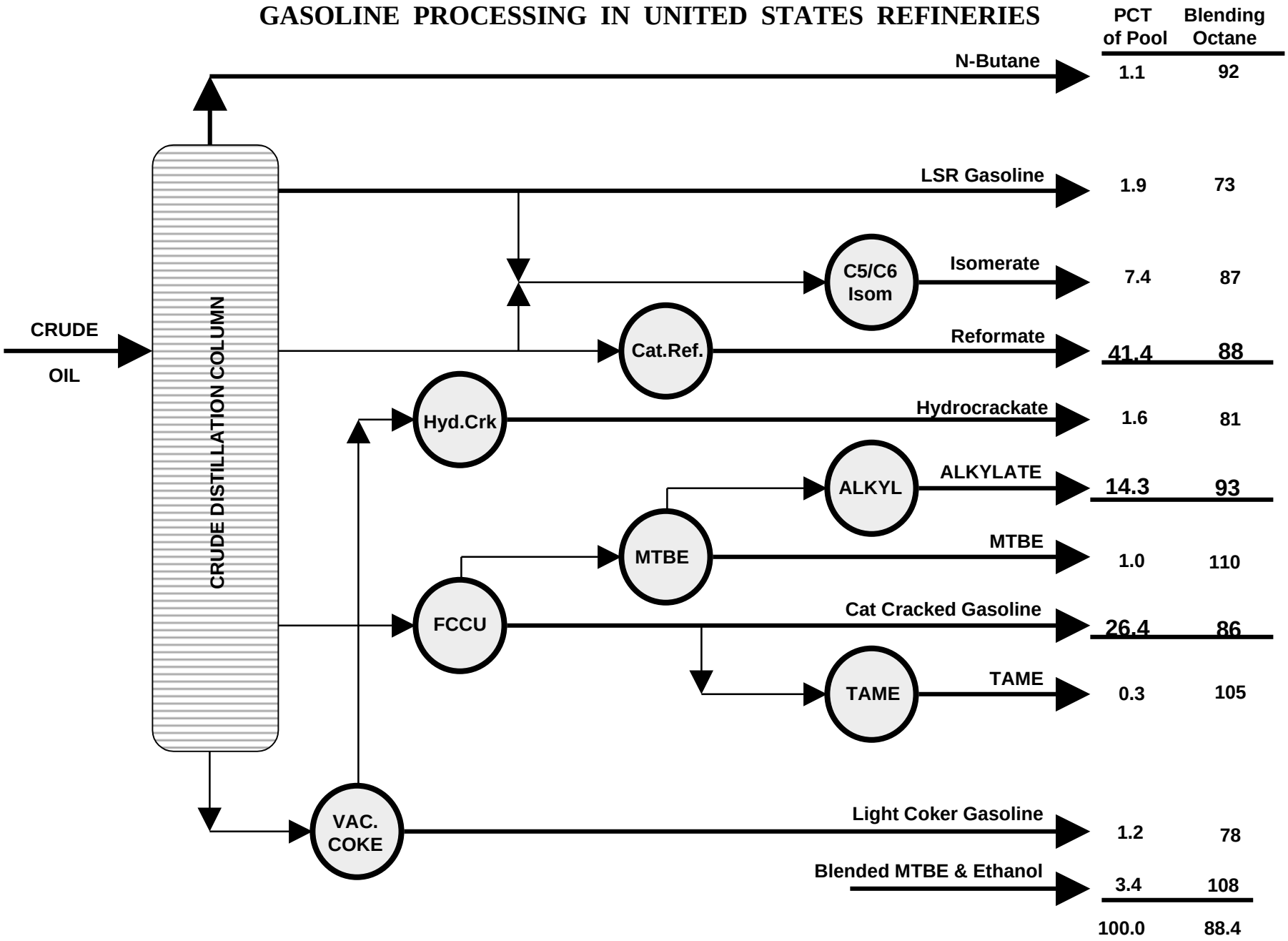
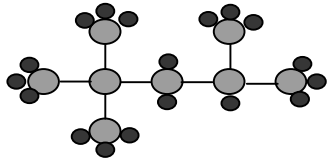


The Structure of Gasoline Production Today
Governed by ASTM Spec. D 4814 & CAA
Eleven Significant Blendstocks
Each Has Unique Properties of Octane, etc.
Reformate, Cat Cracked Gasoline Account for 67%
Alkylate has 14%
Refiners Can Blend in Many Ways, but must
Always meet Octane, RVP, and Boiling Points
Oxygen, Aromatics, Olefins and Sulfur


GASOLINE PROCESSING IN UNITED STATES REFINERIES
PCT of Pool
Blending Octane
N-Butane
1.1
92
LSR Gasoline
1.9
73
C5/C6 Isom
Isomerate
7.4
87
CRUDE OIL
CRUDE DISTILLATION COLUMN
Cat.Ref.
Reformate
41.4
88
Hyd.Crk
Hydrocrackate
1.6
81
ALKYL
ALKYLATE
14.3
93
MTBE
MTBE
1.0
110
FCCU
Cat Cracked Gasoline
26.4
86
TAME
TAME
0.3
105
VAC. COKE
Light Coker Gasoline
1.2
78
Blended MTBE & Ethanol
3.4
108
100.0
88.4

ALKYLATES
Key Components in Clean-Burning Gasoline



Alkylate

is produced by Reacting C3 and C4 Olefins with Isobutane.

Olefins

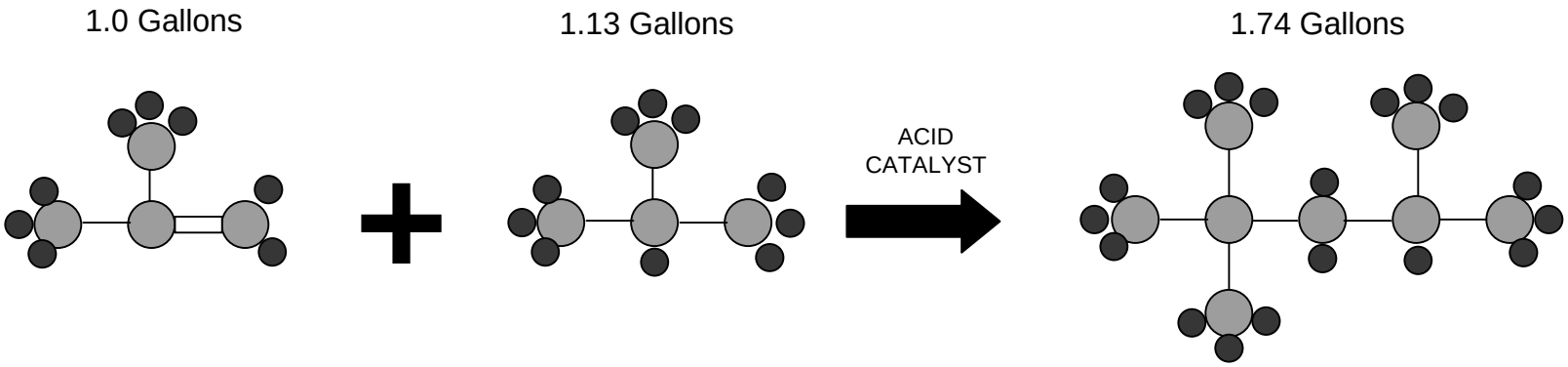
are produced by the Catalytic Crackers

Have limited range for expansion

Most refiners

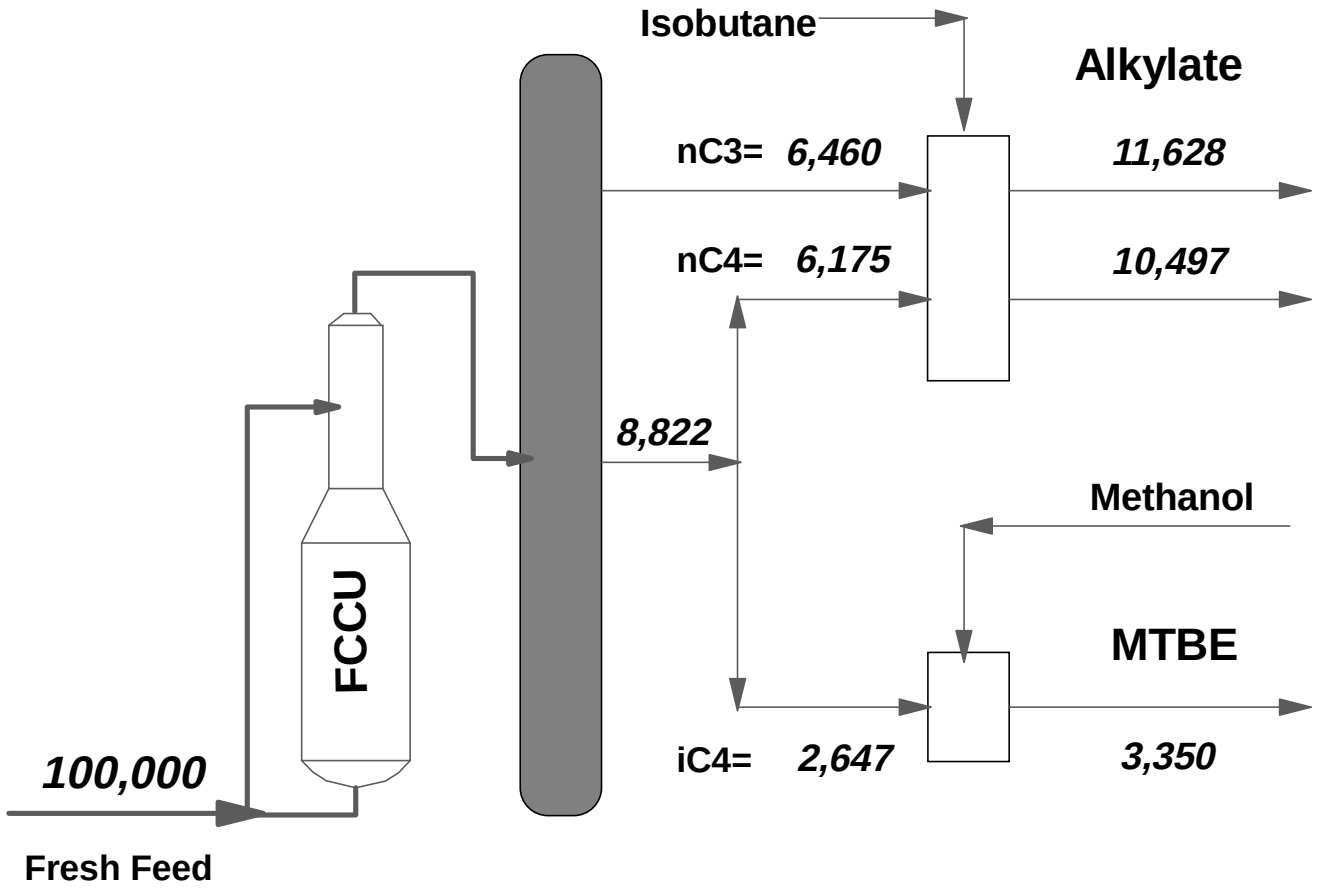
have alkylation capacity matching the Cat Crackers

The Alkylation Reaction



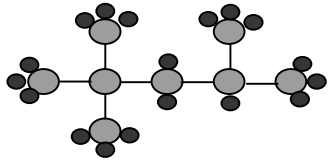
Note: When mixed butylenes are fed to the reaction, a similar process takes place. The overall octane for mixed feed is about 94.5 vs 100 for pure isobutylene feed.
As produced in a refinery, a typical alkylate contains about 26% isooctane, and about 25% of other alkylated octanes.

Typical Fluid Catalytic Cracker Yields of C3 and C4 Olefin Streams



Note: Typical yields
Based on 23 API Feed
80% Conversion

ALKYLATES
Key Components in Clean-Burning Gasoline



CALIFORNIA Consumes

915,000 B/D of gasoline

435,000 B/D of Reformate

168,000 B/D of Cat Cracked Gasoline

165,000 B/D of Alkylate

99,000 B/D of MTBE

REFINERS IN CALIFORNIA

Have limited possibilities for Alkylate Increases

Will be hard pressed to replace the lost volume

California Gasoline Production in B/D

Blending Characteristics

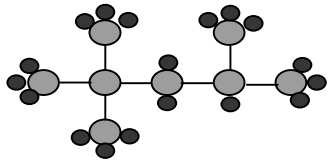
Unit	Capacity	Blendname	Output	Octane (R+M)/2	VPBI psi^1.25	Olefins	Aromatics Bz	Tol	Xyl	C9's	Total
Crude	1,882,850	LSR	0	73.1	25.40	0	0	0	0	0	0
C56 Isom	104,700	Isomerate	100,512	87.0	34.27	704	141	478	605	183	1,407
Thermal	519,000	Lt Coker	39,859	78.2	24.68	14,030	179	610	771	233	1,794
FCCU	636,900	C5+ gas	168,142	86.4	11.59	48,929	4,910	16,693	21,112	6,383	49,097
Reformer	520,400	Reformate	434,638	84.0	3.95	869	7,146	90,948	109,138	31,182	238,415
Alkylation	171,600	Alkylate	164,736	92.1	13.24	824	66	224	283	86	659
Hydrocracker	464,970	Lt hydrocrk	44,637	80.9	23.50	89	121	410	518	157	1,205
MTBE	99,000	MTBE	99,000	110.0	13.45	0	0	0	0	0	0
TAME	5,000	TAME	4,800	105.0	3.14	0	0	0	0	0	0
			1,056,324	88.1	12.00	65,445	12,562	109,364	132,428	38,223	292,577
				RVP-->	7.30	6.2%	1.2%	10.4%	12.5%	3.6%	27.7%
		Export to AZ	80,000	CARB Flat	7.00	4.0%	1.0%				25.0%
		NV	30,000								
		CO	25,000								
		HI	6,000								
			141,000								
		Used in California	915,324								

ALKYLATION SITUATION IN CALIFORNIA REFINERIES

			Max. from FCCU		Fraction Used	
Company	Location	Alky	C4 Alky	C3 Alky	C4=	C3=
Chevron U.S.A.	Richmond	32,000	11,480	9,030	ALL	227%
Atlantic Richfield Co.	Carson-Watson	14,000	15,088	11,868	93%	None
Equilon Martinez Refy Co.	Martinez	10,600	11,414	8,978	93%	None
Equilon Enterprises LLC	Wilmington	9,000	5,297	4,167	ALL	89%
Tosco	Wilmington	16,500	7,708	6,063	ALL	145%
Tosco	San Francisco	15,000	10,906	8,579	ALL	48%
Mobil Oil Corp.	Torrance	22,000	14,842	11,675	ALL	61%
Exxon Co.	Benicia	14,000	11,316	8,901	ALL	30%
Ultramar Diamond Shamrock	Wilmington	10,500	6,232	4,902	ALL	87%
Chevron U.S.A.	El Segundo	28,000	10,168	7,998	ALL	223%
		171,600	104,452	82,160		

Note: Not much room here for expanded Alkylate production, except perhaps by Chevron

ALKYLATES
Key Components in Clean-Burning Gasoline



Refiners Elsewhere in the USA

- **Have about the same yield structure as in California**
- **Are fully built up with respect to Alkylate Capacity**
- **Cannot really produce any extra for California**
- **Will also have volume problems if all USA drops MTBE**

United States Gasoline Production in 1998 in Barrels per Day

Blending Characteristics

Unit	Capacity	Blendname	Output	Octane (R+M)/2	VPBI psi^1.25	Olefins	Aromatics Bz	Tol	Xyl	C9's	Total
Crude	15,975,365	LSR	154,961	73.1	25.40	3,409	434	1,475	1,866	564	4,339
C56 Isom	615,025	Isomerate	596,574	87.0	34.27	4,176	835	2,840	3,591	1,086	8,352
Thermal	2,506,724	Lt Coker	97,261	78.2	24.68	34,236	438	1,488	1,882	569	4,377
FCCU	5,897,430	C5+ gas	2,108,007	86.4	11.59	613,430	61,554	209,283	264,681	80,020	615,538
Reformer	4,130,770	Reformate	3,320,674	87.0	3.95	6,641	58,554	745,237	894,285	255,510	1,953,587
Alkylation	1,186,280	Alkylate	1,150,692	92.6	13.24	5,753	460	1,565	1,979	598	4,603
Hydrocracker	1,480,570	Lt Hydrocrk	129,254	80.9	23.50	259	349	1,187	1,501	454	3,490
n-Butane		n-Butane	89,000	92.0	139.64	0	0	0	0	0	0
Ethanol		Ethanol	90,900	105.0	29.52	0	0	0	0	0	0
MTBE		MTBE	280,786	110.0	13.45	0	0	0	0	0	0
TAME		TAME	22,126	105.0	3.14	0	0	0	0	0	0
			8,040,235	88.3	12.63	667,904	122,624	963,075	1,169,785	338,801	2,594,285
5/19/99 12:37				RVP-->	7.61	8.3%	1.5%	12.0%	14.5%	4.2%	32.3%

ALKYLATES
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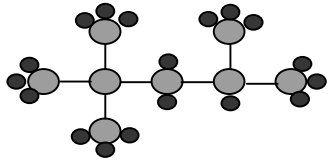
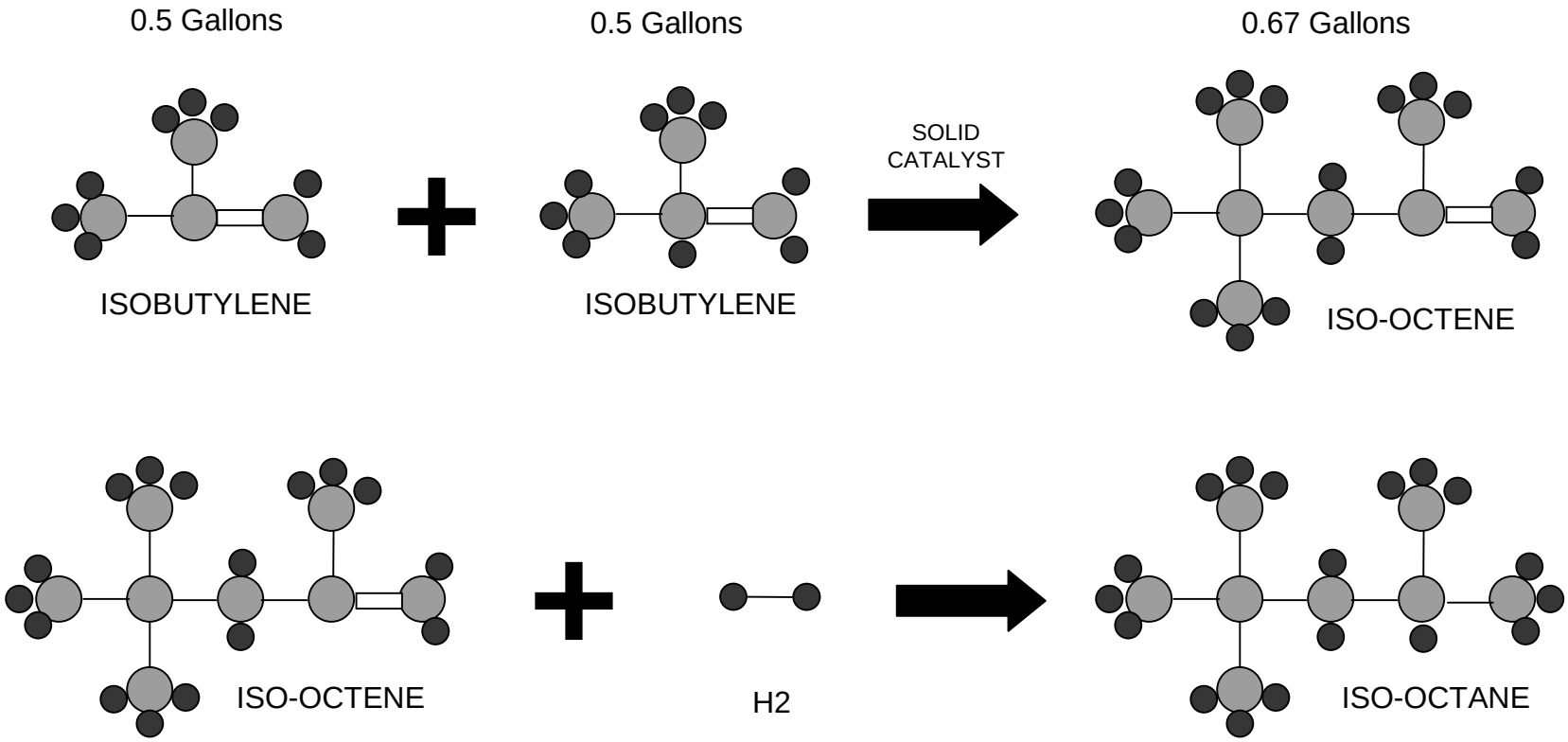


Potential Sources of Additional Alkylates or Similar Blendstocks

Convert MTBE plants to make Alkylate	**VERY EXPENSIVE**
Convert MTBE plants to make Isooctane	**EXPENSIVE**
Use Raffinates from Olefins Plants	**HAVE OTHER USES**

Iso-Octane via Polymerization of Iso-Butylene



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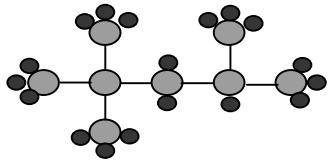

Potential Cumulative New Products from Shutdown MTBE Plants

Year	Alkylate	IsoOctane
2003	73,500 B/D	46,400 B/D
2005	176,000	111,100
2007	271,200	171,200
Capital Cost	$1.1 Billion	$385 Million

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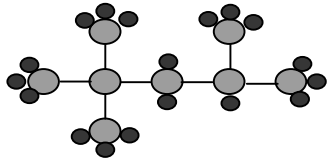

CONCLUSIONS

ALKYLATES are Excellent and Widely-Used Blendstocks for Gasoline

They have: High Octane (92-94)

Very small contents of Olefins, Aromatics, & Sulfur

OPPORTUNITIES for Expanded Use are Limited

ALKYLATES
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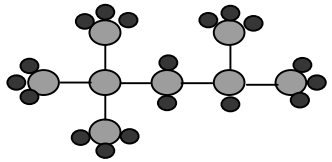

CONCLUSIONS

ALKYLATES ARE INFERIOR TO MTBE in Clean-Air Gasoline

- **10-15 Octanes Lower**
- **Higher T10 and T90 Points**
- **No Oxygen**

ETHANOL is ALSO LIMITED

- **Slightly Lower Octane**
- **Vapor Pressure**
- **Dilution Effect Smaller**

A TOTAL LOSS OF MTBE OUTSIDE OF CALIFORNIA

- **Would require DRASTIC reductions in RFG Quality**